METHOD FOR CURING RESIN WITH ULTRASOUND

FIELD

The present patent application relates to methods for curing polymeric materials and, more particularly, to methods for curing polymeric resins using ultrasound, wherein the cured resins are useful for bonding and/or for the formation of various articles, including composite materials.

BACKGROUND

Synthetic resins, such as epoxy resins, polyester resins and the like, are commonly used as adhesives for bonding two substrates together. However, synthetic resins are also combined with appropriate substrates, such as fibers, glass, metals and wood, to form composite materials. Such composite materials find application in a variety of fields and industries. For example, synthetic resin-based composite materials are used in the aerospace industry to form parts, propellers, tails, wings and fuselages.

Composite materials typically are formed by preparing the synthetic resin (e.g., mixing a polymer with a catalyst), combining the substrate with the synthetic resin, molding the substrate and resin mixture into the desired shape, and curing the molded substrate and resin mixture until it achieves the desired physical properties. Once cured, the resulting composite material may be removed from the mold, at which point it is ready for use, packaging or further processing.

Common molding techniques include vacuum bag molding, pressure bag molding and autoclave molding. In vacuum bag molding, a mold or form, such as a two-sided mold, is filled with the substrate and resin mixture and placed into a vacuum bag. Then, a vacuum is drawn in the vacuum bag to urge the substrate and resin mixture into the various nooks and crannies of the mold. The vacuum bag is then sealed and cured.

Various techniques have been presented for curing synthetic resin. Most commonly, heat is used to cure resins. For example, sealed vacuum bags may be cured in an oven for a predetermined amount of time. However, alternative techniques for curing synthetic resins include the application of high pressure, whether alone or in combination with heat, as well as exposure to ultraviolet light.

Despite the advances in the field of synthetic resin curing and composite material formation, those skilled in the art continue to seek new techniques for curing synthetic resins and forming composite materials.

SUMMARY

In one aspect, the disclosed method for curing a resin may include the steps of positioning the resin in a gaseous coupling fluid and applying ultrasonic energy to the gaseous coupling fluid until the resin becomes a solid mass.

In another aspect, the disclosed method for curing a resin may include the steps of placing the resin into an appropriate reaction vessel, drawing a vacuum in the reaction vessel, positioning the vacuumed reaction vessel in a gaseous coupling fluid, and applying ultrasonic energy to the gaseous coupling fluid.

In another aspect, the disclosed method for curing resins may include the steps of placing an epoxy resin into an appropriate vessel, such as a film pouch, the epoxy resin including a catalyst, sealing the vessel, positioning the sealed vessel in a gaseous coupling fluid, and applying ultrasonic energy to the gaseous coupling fluid at least until the epoxy resin becomes a solid mass.

In another aspect, the disclosed method for curing resins may include the steps of placing an epoxy resin into a vacuum bag, the epoxy resin including a catalyst, placing a mold into the vacuum bag, drawing a vacuum in the vacuum bag, sealing the vacuum bag, positioning the sealed vacuum bag in a gaseous coupling fluid, and applying ultrasonic energy to the gaseous coupling fluid at least until the epoxy resin becomes a solid mass.

Other aspects of the disclosed method for curing resin will become apparent from the following description, the accompanying drawings and the appended claims.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a block diagram of an apparatus for curing resins in accordance with an aspect of the disclosed method for curing resin; and

FIG. **2** is a flow chart illustrating a particular aspect of the disclosed method for curing resin.

DETAILED DESCRIPTION

The first observation of the effect of ultrasonics was the discovery in 1894 by Sir John I. Thornycroft and Sydney W. Burnaby. Messrs. Thornycroft and Burnaby observed that severe vibrations caused the erosion of a ship's propeller, and that the erosion was attributable to the formation and collapse of tiny bubbles that from at the propeller. Over the years, knowledge of ultrasound has grown. Today, the generation and use of ultrasonic energy is found in various applications.

Ultrasound (also referred to as "ultrasonic energy") can be transmitted through any material possessing elastic character. For example, when ultrasonic energy is applied to a liquid, the molecules in the liquid vibrate. As the average distance between the molecules in the liquid exceeds the critical molecular distance that holds the liquid intact, the liquid breaks down forming bubbles that cavitate. These bubbles can be filled with gas or vapor and occur in various fluids including water, organic solvents, biological fluids, liquid helium, molten metals and the like.

It has been determined that the collapse (i.e., cavitation) of ultrasonically-formed bubbles results in localized temperatures as high as 5000° C. and pressures as high as 1000 atmospheres for a lifetime of less than one microsecond. Thus, the cavitation of a fluid due to exposure to ultrasound results in a tremendous concentration of localized energy in an otherwise relatively cold fluid.

It has now been discovered that ultrasonic energy, and the phenomena associated therewith, can be used to cure various synthetic resins, which may ultimately be used in the formation of composite materials, adhesive bonding, and the repair of damaged composite materials. Indeed, when ultrasound is used to cure synthetic resins, it may eliminate the need for heat and may also expedite the curing process relative to other curing techniques.

As shown in FIG. **1**, an apparatus for curing resins, generally designated **10**, may include a reaction vessel **12**, an ultrasound transducer **14**, a gaseous coupling fluid **16** and a resin **18** (shown generally as a block). The resin **18** may be positioned in the reaction vessel **12** and the reaction vessel **12** may be positioned in the gaseous coupling fluid **16** such that ultrasonic energy may pass from the ultrasound transducer **14**, through the gaseous coupling fluid **16** and to the resin **18** in the reaction vessel **12**, thereby curing the resin **12** therein.